International Comparison of Refractive Index Measurements

Andreas Fricke, Michael Schulz

Physikalisch-Technische Bundesanstalt (PTB),
Bundesallee 100, 38116 Braunschweig, Germany

mailto:andreas.fricke@ptb.de

Recently, an international comparison on refractive index measurements was initialized by PTB and Schott AG. As specimens, prismatic samples or raw glass can be provided for the participants. The homogeneity of the glass blanks for sample preparation is one prerequisite and it is determined including the linear contribution by a wavelength shifting interferometer.

1 Introduction

For optically transparent materials the refractive index is an important quantity which has to be known with absolute uncertainties in the range of 10^{-6} for many high-tech applications. Most highly accurate refractive index measuring instruments apply the beam deviation by prismatic samples as the measurement principle.

Metrological comparisons of refractive index measurements are important for cross-checking different setups. A former comparison with 13 participants, performed about 10 years ago, used only prismatic samples [1]. Now a new international comparison has been initialized by Schott AG and PTB (pilot laboratory) using prismatic samples, or alternatively non-polished samples or even “raw” pieces of the glass material. In the following, the concept of the comparison, the setup of PTB, and homogeneity measurements will be presented.

2 The concept of the comparison

For the comparison, the table below shows the sample glasses chosen for the measurements.

Glass type	n_d
SF57 (HHT)	1.84
SF64	1.71
LAK8	1.71
Fused Silica	1.46

Tab. 1 *Selected sample glasses and nominal refractive indices*

If possible, a defined set of wavelengths between 365 nm and 1013 nm shall be measured by the participants. Additionally, a set of other preferred wavelengths can be measured.

The samples will be distributed by PTB. These can either be polished prisms, prisms with unpolished surfaces or raw pieces of glass. This selection of possible samples was chosen to also incorporate the influence of the prism manufacturing into the comparison. Participants able to polish the prisms themselves or those who have a customary manufacturer should use this option. This “ab initio” determination of the refractive index from raw glass pieces is preferred because it includes the influence of non-perfect prism surfaces, thus emulating the practice used in glass manufacturing and testing.

3 Refractive index measuring setup of PTB

The instrument used at PTB for refractive index measurement of solid prismatic samples was built in an early cooperation of PTB and DR. JOHANNES HEIDENHAIN GmbH [2]. Recently, it has been improved by a new angle encoder. The measuring method is the minimum deviation method [3], where the path through the prism is symmetric. Fig. 1 illustrates the method (the green line denotes the optical beam path) and table 2 shows the influence of the most important parameters on the measurement uncertainty.

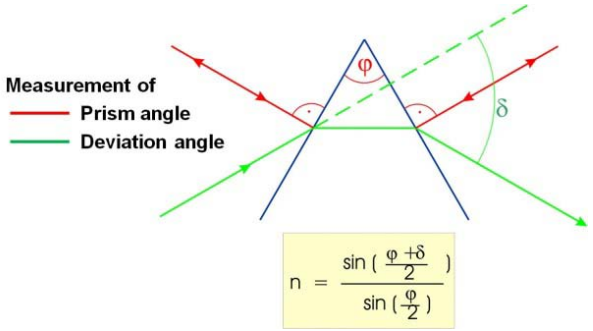

Fig. 1 *Minimum deviation method with symmetric paths. The result for n has to be corrected for the refractive index of the surrounding air.*

For solid glass samples, the expanded measurement uncertainty [4] can be as low as 1.0…1.4 • 10^{-6} (for n = 1.5…1.9). For liquid samples, a prismatic cell is used, but the measurement uncertainty typically is about one order of magnitude higher

due to the higher temperature coefficients of liquids.

Parameter	Uncertainty	Unc. contribution
Prism angle	0.04 arcsec	$1 \cdot 10^{-7}$ (n = 1,5) $5 \cdot 10^{-7}$ (n = 1,9)
Deviation angle	0.13 arcsec	$4 \cdot 10^{-7}$ (n = 1,5) $5 \cdot 10^{-7}$ (n = 1,9)
Temperature	0.005 K	$1 \cdot 10^{-7}$
Refractive index air	$3 \cdot 10^{-7}$	$3 \cdot 10^{-7}$
Wavelength	$1 \cdot 10^{-3}$ nm	$3 \cdot 10^{-8}$
Minimum position prism	3 arcsec	$1 \cdot 10^{-8}$
Pyramidal error	10 arcsec	$1 \cdot 10^{-7}$
Flatness prism surfaces	50 nm	$4 \cdot 10^{-7}$
Homogeneity prism	50 nm	$4 \cdot 10^{-7}$

***Tab. 2** Uncertainty contributions*

4 Sample homogeneity

Using glass blanks as initial specimens requires that the index of refraction is sufficiently homogenous across the blanks. Otherwise, if different samples manufactured from different parts of the glass blank differ too much in local refractive index, the results will not be comparable.

For homogeneity measurements, a wavelength shifting interferometer (Zygo VeriFire MST) is used which has the capability of measuring multiple cavities simultaneously and separating them by Fourier analysis of the spectrum after the measurement (see Fig. 2).

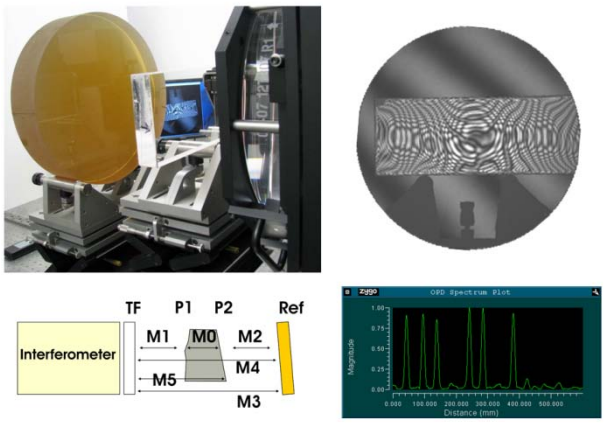

***Fig. 2** Homogeneity measurement. The fringe pattern is determined by multiple cavities which can be selected from the spectrum shown at the bottom right.*

From the different cavities, the homogeneity can be determined as described by Schwider et al. [5]. One should note that the formulas given in that publication apply also to the case where the single cavities can be determined with a valid linear contribution.

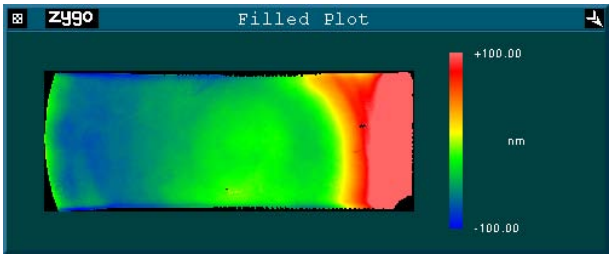

***Fig. 3** Optical path length variation for a Lithosil sample*

Fig. 3 shows the optical path length variation for a Lithosil blank. While the right area of the blank shows a strong inhomogeneity, the left and central areas have a homogeneity of better than $7 \cdot 10^{-7}$ and sample specimens should be manufactured from these parts of the glass blank.

It must be ensured that the tilt is not too high in the single cavities, because otherwise the interferometer will not meet the common path criterion and retrace errors may influence the homogeneity estimation.

5 Conclusion

The new international comparison of refractive index measuring instruments will include influences of the manufacturing of the samples for those participants that are able to do this on their own responsibility. For those participants who are not able to manufacture prisms, prismatic samples will be provided. The comparison has started recently and additional participants are welcome.

The homogeneity of refractive index is one prerequisite for the provision of suitable samples. Appropriate homogeneity measurements can be performed with a wavelength shifting interferometer available at PTB. Thus, suitable glass blanks can be selected for the manufacture of the various specimens of the refractive index measurement comparison.

References

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